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3. River Systems

The purpose of this section of the report is to describe generally what a river system is, how it functions and how it is used. The role of flooding in a river system is explained, from both the standpoint of its dynamic nature as the lifeblood of the system, and as the predominant force that shapes and rearranges fish and wildlife habitats and provides natural resources for human uses. Our alterations of river systems to exploit these resources are briefly described, together with the consequences of our actions once we begin to prevent floodplains from flooding. Finally, the ways in which we have managed our uses of floodplains in river systems are discussed, with respect to past trends in flood control costs and flood damages, and future trends toward more sustainable floodplain management.

3.1 The River System

A river system is the expression of water on the landscape. Water, to a large extent, originates from precipitation in mountainous **uplands**, flows through floodplain-dominated **lowlands** and, in many cases, discharges to ocean **estuaries**. The water moving through each of these areas connects the landscape into one system, making it impossible to talk about the lowland and estuary without acknowledging the contribution to these areas made by the uplands. The floodplains of the lowlands are the areas where the conflicts between human flood risk and salmon habitat are most evident.

Over the past decades, we have used a number of engineering approaches to “control” flooding. These include regulating the amount of water in the river, and modifying the structure of both the channel and the floodplain. Other alterations have been made to increase the productivity of floodplain lands. These engineering approaches are very costly and, though effective for smaller floods, have not significantly reduced flood damages in large flood events. This, combined with an increasing desire to preserve ecological integrity, has begun to change the way we manage floodplains. Land managers are increasingly combining flood damage reduction goals with goals for preservation and restoration of aquatic and terrestrial habitats, and are attempting to use flooding as a way to create and maintain those habitats.

3.2 Flooding and Floodplain Functions

River systems transport water, sediment, and nutrients from the land to the sea, shaping and reshaping floodplains, deltas, and beaches, and regulating the salinity and fertility of the water and land. Floods facilitate these functions, by providing energy to introduce and transport materials in the river system,

and in doing so, maintain biodiversity. In upland forests, heavy rains may cause landslides which can introduce wood and sediment to the river system. These materials are transported downstream to the lowlands, where they are deposited in channels and on floodplains, and reworked with the next flood. Flooding along lowland rivers may also introduce sediment and wood to the river system from riverbank and bed erosion. Flooding in the lowlands introduces a lateral dimension to the downstream movement of these materials, as floodwaters spill over riverbanks and then recede back into the channel as the flood passes. Flooding within the larger land areas of estuaries, where floodwater velocity and energy tends to diminish, typically results in the deposition of transported materials. However, tidal action in estuaries introduces another dimension to the movement of water as daily flood and ebb tides rhythmically flow, or aggressively surge inland with ocean storms and clash with river floodwaters flowing seaward. The dynamic mixing of water in the estuary during regular tides and infrequent storm surges results in complex patterns and reworking of sediment and wood, and a changing interface of fresh and salt water. This complexity is an essential part of the hydrological and ecological function of a river system.

Flooding, therefore, is a part of the dynamic nature of a healthy river system. The flood pulse is both a product of and an influence on geomorphic and hydrologic conditions. Flood pulses (Junk *et al.*, 1989) are one of the principle driving forces responsible for the existence, productivity, and interactions of the life forms in a river system (Figure 3-1). High instream flows and periodic overbank floods are needed to cleanse channels of accumulated sediments, build stream banks, cycle nutrients, transport gravel for spawning fish, and create landforms suitable for riparian forest recruitment.

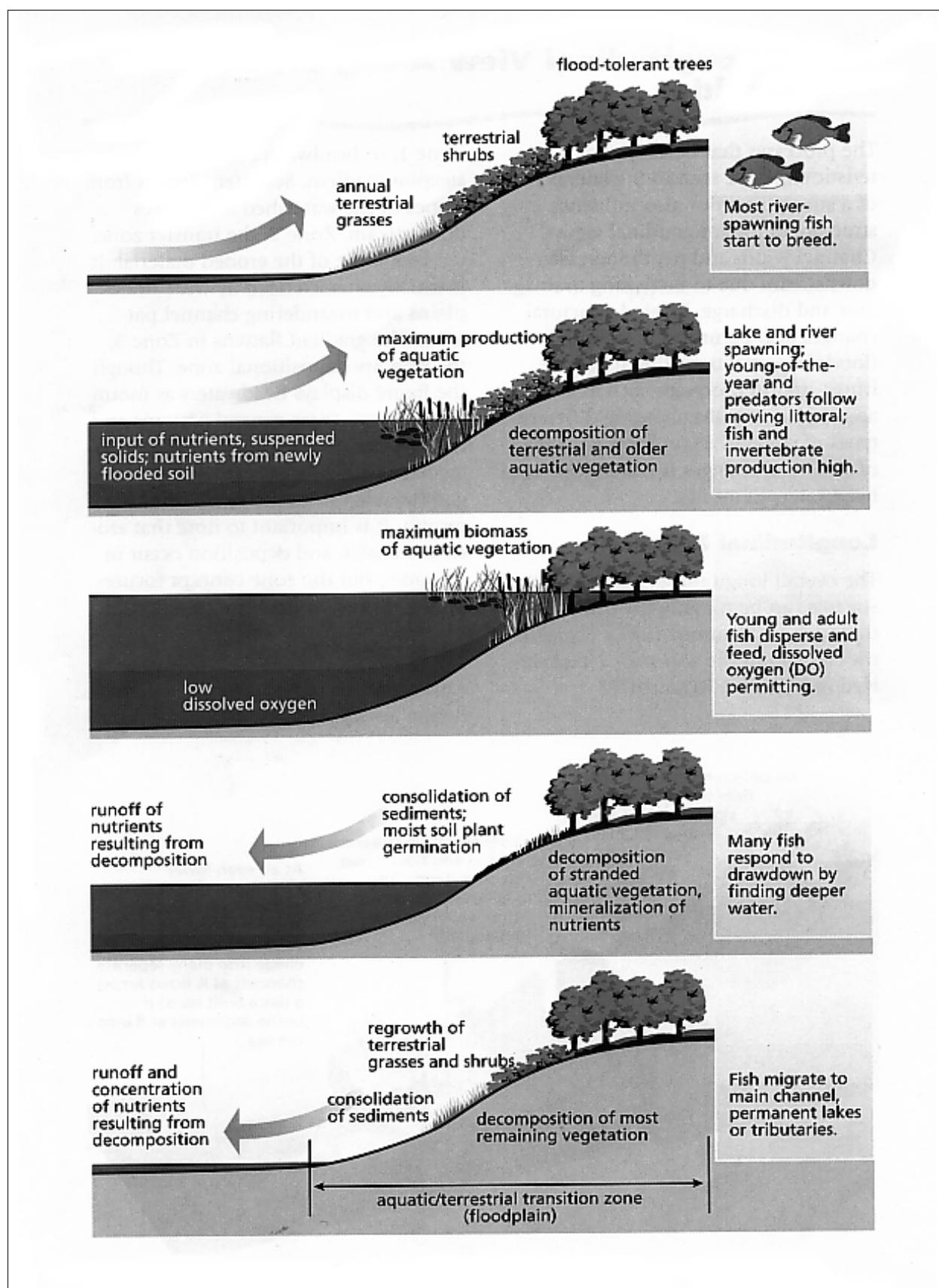


Figure 3-1. Schematic of the Flood-Pulse Concept Source: Bayley, 1995

A vertically exaggerated section of a floodplain in five snapshots of an annual hydrological cycle. The left column describes the movement of nutrients. The right column describes typical life history traits of fish.

Small frequent floods and larger infrequent floods are responsible for the creation and evolution of the lowland floodplains, with the size of floods in the lowlands directly related to the contribution of water from the uplands. More frequent floods are generally thought to maintain the form of a river in the short-term, while less frequent, higher magnitude floods affect river form over a longer time-scale. The constant readjustment of river form with these changing flows is called dynamic equilibrium. Seasonal flooding promotes the exchange of materials by facilitating erosion and deposition. As a result, flooding enhances seed dispersal, seedling survival, and the growth of many native plant species that occupy channel banks and floodplains (Hill *et al.*, 1991). In this way, flood pulses lead to a mosaic of habitats that determine the level of biological productivity and diversity in the river and on the floodplain (Petts, 1996).

Flooded lands in a river system, or floodplains, serve as both sources and sinks for transported material. They also dampen flood flows and provide diverse habitats. A floodplain is defined as the relatively level valley floor formed of sediment deposits (Anderson *et al.*, 1996) (Figure 3-2). In an unmodified state, this is the flat area adjacent to a river channel which is periodically flooded when flows exceed the channel capacity (Bren, 1993). From the flood pulse concept, the floodplain is the aquatic/terrestrial zone where the production of aquatic vegetation, decomposition of vegetation and consolidation of sediments occurs (Figure 3-1).

During flood events, a river overflows onto its floodplain, and the capacity of the system to convey and store large volumes of water is temporarily increased. The storage of water on floodplains reduces the peak stage of flood events downstream as floodwaters spread out and are held on the floodplain. During this process,

sediment, wood and nutrients are provided to surrounding riparian land and aquatic habitat, increasing floodplain productivity.

The ability of a river to overflow onto its floodplain helps to moderate bank erosion and channel change. Streamflow in rivers that are confined in canyons or between levees has greater power because the flow is concentrated into a small flow area and is deeper than if it were allowed to spread out. This concentrated stream power can result in bank erosion and channel changes that would be less severe if the river were able to overflow. In rivers with floodplains, water flow and volume spread out onto the floodplain during high flow events, reducing the stream power acting on the channel bed and banks. Lower stream power can result in more stable channels. Floodplains therefore serve as a kind of “pressure release valve” by moderating the rise of water levels and channel velocities during flood events.

Floodplain overflows can therefore lessen the destructive force of floodwaters. This benefits riparian habitats, by lowering the erosive force of flowing water to levels that can be withstood by the native vegetation important to fish and wildlife habitat. Human investments along the river system may also benefit because lower erosion potential can reduce damage to protected riverbanks. By allowing floodplains to flood, there may be less need for riverbank protection.

The ability of a river to overflow onto its floodplain helps to moderate the tendency of an otherwise constrained river channel to fill with debris and sediments. The murky brown color of floodwaters is an indication of the significant amount of sediment transported in a river system during flood events. The flow of sediment-laden floodwaters, carrying floating debris out of the river channel and across a wide floodplain, can result in wider distribution of sediment and debris as floodwaters recede. Shallow floodplain flows encounter more resistance from vegetation along

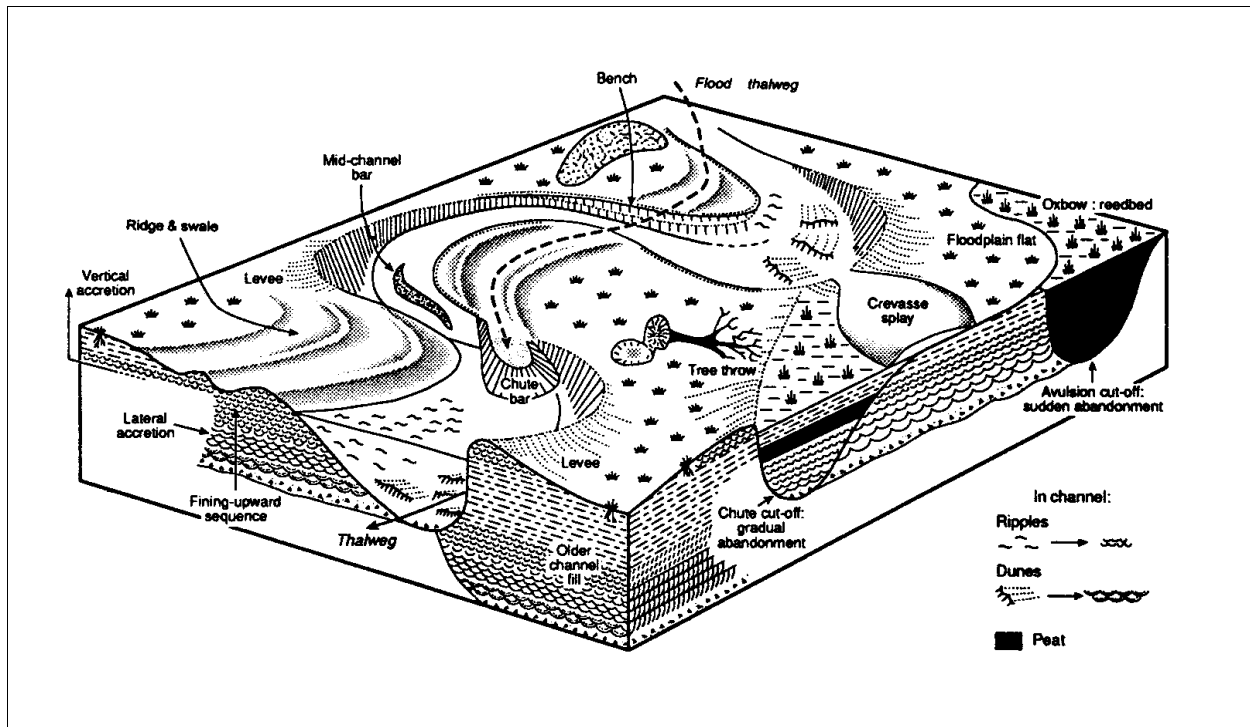


Figure 3-2 River Floodplain Landform Schematic Source: Brown, 1996

river banks and across the floodplain, causing the moving water to lose energy and deposit suspended sediment and debris. Where floodwaters first encounter the filtering effect of riverbank and floodplain vegetation, large amounts of sediment are deposited, forming low natural levees along the river channel. Natural floodplains are able to capture and store enormous volumes of suspended sediment spread over large areas, which helps reduce the amount of sediment transported to channels and estuaries downstream.

3.3 Flooding and Fish and Wildlife Habitats

Flooding alters the structural complexity of upland forest and lowland floodplain landscapes, and rejuvenates the plant communities that grow in them.

Over time, periodic flooding results in plant communities made up of a mosaic of vegetation species and ages. This complexity, in turn, supports a diversity of terrestrial and aquatic animal species, including

salmon. Flooding contributes to species diversity by:

1. creating varied landforms that support diverse native plant communities;
2. creating a variety of habitats, including spawning habitat for fish;
3. creating low-velocity refugia for fish and other aquatic organisms during floods;
4. contributing to the aquatic food web by collecting, cycling, and transporting organic matter from the uplands to the lowlands and from the floodplain back to the channel;
5. maintaining water quality by filtering excess sediment and nutrients from flood flows and providing shade.

The riparian portions of floodplains have a great amount of structural complexity, and are highly functional parts of a river system. They often include complex arrangements of live trees and shrubs, downed wood and trapped flood debris. The functions of riparian

floodplains lead to in-stream effects that shape and reshape salmon habitat (Figure 3-3). Flooding serves as the lifeblood to sustain these riparian functions and maintain habitats.

Flood flows mobilize and rearrange gravel and cobble deposits in the lowlands and estuary, left from previous flood events. They transport and redistribute sand and fine sediments from eroding banks or low bars on outside bends and from point bars. These newly formed channel features are colonized by a variety of native plant species, and provide accessible edge habitats. Flood flows also sort gravel deposits in a river channel as floodwaters recede. This results in river reaches with collections of gravel suitable for salmonid spawning habitat. When a flood retreats from the floodplain, the decreasing flows and water depths result in the deposition of sediments and debris on the floodplain. This enhances the build-up of natural mounds and ridges that can trap subsequent floodwaters and create shallow marshy basins on floodplains. These wetlands and other remnant channel features, such as oxbows, and scrolls (Figure 3-3), provide sheltered refuges for fish from high flows. This refuge habitat is especially important for juvenile fish, which need lower velocity and cleaner water to survive.

Floods also supply large wood and organic detritus to the river and its floodplain. Large wood affects the geomorphology and hydraulics of the stream, which, in turn, regulates light penetration to the stream, and the input of dissolved and particulate matter. Together, these functions regulate the food supply and energy expenditure of salmon.

Saturation of floodplain soils from flooding, and resulting elevated groundwater levels, enhance and sustain riparian vegetation and wetlands along rivers.

Permeable floodplain lands can absorb large quantities of floodwater when made available for flooding, and vegetation and depressions in the terrain slow and hold the water and allow it to sink into absorbent soils.

When flooding can recharge groundwater and raise water tables under floodplains in the winter and spring seasons, this stored water may slowly seep back to the river later in the year after floodwaters recede. Water released back to the river system in this way can benefit water quality by contributing cool groundwater during warm summer months. Floodplain groundwater can also contribute to the quantity of flowing water from upstream sources and reduce the chances of river beds and banks drying up and stressing vegetation and fish. In a sense, floodplains can be viewed as natural reservoirs that can provide storage of floodwaters both above ground, during flood events, and below ground after floods have passed.

Flooding provides sediment and nutrients to both the flooded lands and aquatic habitats (Federal Interagency Floodplain Management Task Force, 1996). As floodwaters pass over floodplain land, they capture soil particles and organic material rich in carbon and nutrients. These materials are transported across the floodplain at high flows to backwater basins, estuaries, secondary channels, and ultimately back to the river. These organic components provide microhabitats, food, and nutrients to sustain zooplankton, aquatic invertebrates, and small fish. By detaining floodwaters longer than in the main channels, floodplains also increase the residence time of these organics. This promotes greater energy use, higher food web productivity and improved water quality.

Floodplain vegetation also plays a role in water quality. Riparian trees and shrubs help to shade streambeds and maintain lower water temperatures. This is important

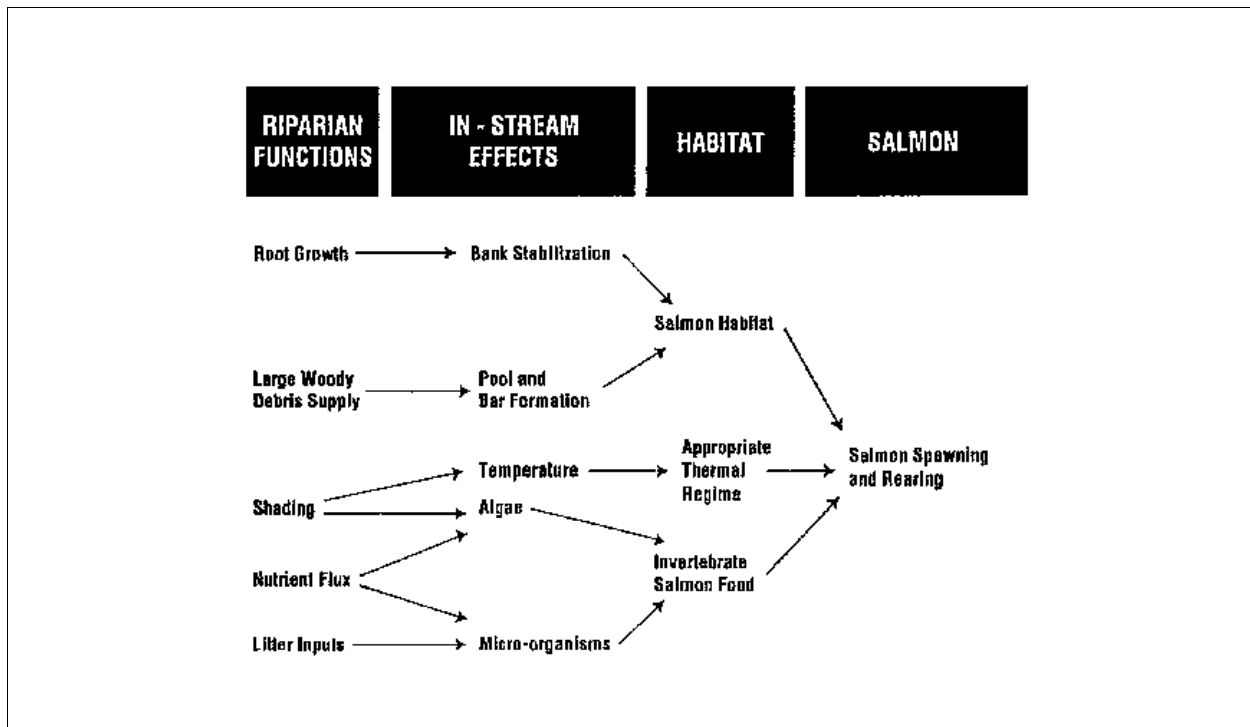


Figure 3-3. Riparian Functional Relationship to Salmon Source: Botkin *et al.*, 1995

because cooler water is capable of carrying more dissolved oxygen, which is critical for salmonid health. Floodplain vegetation also helps in filtering sediment.

All these floodplain functions work together to shape and reshape the habitats within which salmon and other species have evolved, and to which they have adapted. Fish and wildlife have, over time, developed intricate physical, chemical and biological relationships linking them within the river system. These relationships--seen and unseen--can be damaged or destroyed when humans alter the river system.

3.4 Human Alterations of the River System

The increasing intensity of human use of upland forests, lowland floodplains, and estuaries has altered river system functions, and, in many instances, has increased

the size and frequency of floods. Our occupation of floodplain lands has decreased our tolerance for periodic flooding.

Human land use has also altered the source, transport and deposition of water-borne materials through the uplands, lowlands, and estuaries of river systems. Timber harvesting on forested uplands has decreased forest cover while increasing the incidence of landslides and debris flows. This has resulted in an increase in the delivery of sediment to rivers, but without the accompanying natural delivery of large wood. Both these changes in river system inputs have had negative effects on terrestrial and aquatic habitat in the lowland and estuary areas downstream. Reduction of forest cover in the uplands and compaction of soils from logging and burns have decreased the natural ability of the forest to absorb water, thereby increasing both the speed and volume of water delivered to the river system as runoff. This in turn increases flood risk in lowland and estuary areas. The downstream results

of these upland alterations have been further compounded by the fact that the increased flood risk in the lowlands is being met with increased development and occupation of the floodplain.

Floodplains are typically the most intensely used land areas in a river system. The earliest lines of transport and communication have typically been located along rivers, and this has led to the early development of floodplains. Floodplains are attractive for many uses because they offer large, flat tracts of land and abundant water. Riparian forests can be removed to create productive pasture and agricultural lands. Deposits of sand and gravel on floodplains and in river channels can be mined for use as aggregate in concrete. A variety of other commercial and industrial land uses is often found on floodplains for various reasons. As the number and value of these land uses has expanded to increase the productivity of floodplain lands, actions have been taken to protect the growing number of investments from flood risk. Many river flood control strategies have included actions that prevent floodplains from flooding.

The traditional assumption that flooding can be completely controlled has led to an over-reliance on man-made flood protection, and the development of flood control systems which constrain rivers into artificially narrow channels and isolate historic floodplains, eliminating or hindering their natural function. Floods have been viewed through the years as anything but a part of the natural life cycle of river systems (Friends of the River, 1996).

As flood control works are built and age over time, continued alterations in the river system often create new flood characteristics that may invalidate the assumptions used to design and build the old flood control facilities. For example, continued development and urbanization in our watersheds has resulted in pavement and efficient storm sewers that speed runoff. Because of the increased rate and volume of runoff, a statistical 100-year flow value from 20 years ago may be much less than that same statistical value today, and correspondingly, today's true 100-year floodplain may be larger than we believe (Figure 3-4).

Over the past two centuries, flood control practices have resulted in radical changes to floodplains. Dams, levees and dikes have been built to control flooding and protect floodplain developments. These responses, ironically, have created a false sense of security and have, in many cases, actually increased flood damages, because when flood control measures fail, flooding often occurs faster and with more disastrous consequences. In addition, human alterations have separated rivers from their floodplains. This has simplified the complex form of the channel and floodplain and reduced the functions provided by the interaction between water and land. This has had negative consequences for native vegetation, terrestrial animal species, and aquatic species like salmon. The following are examples of traditional engineering "solutions" to control flooding and the impact these practices have had on river morphology and salmon habitat.

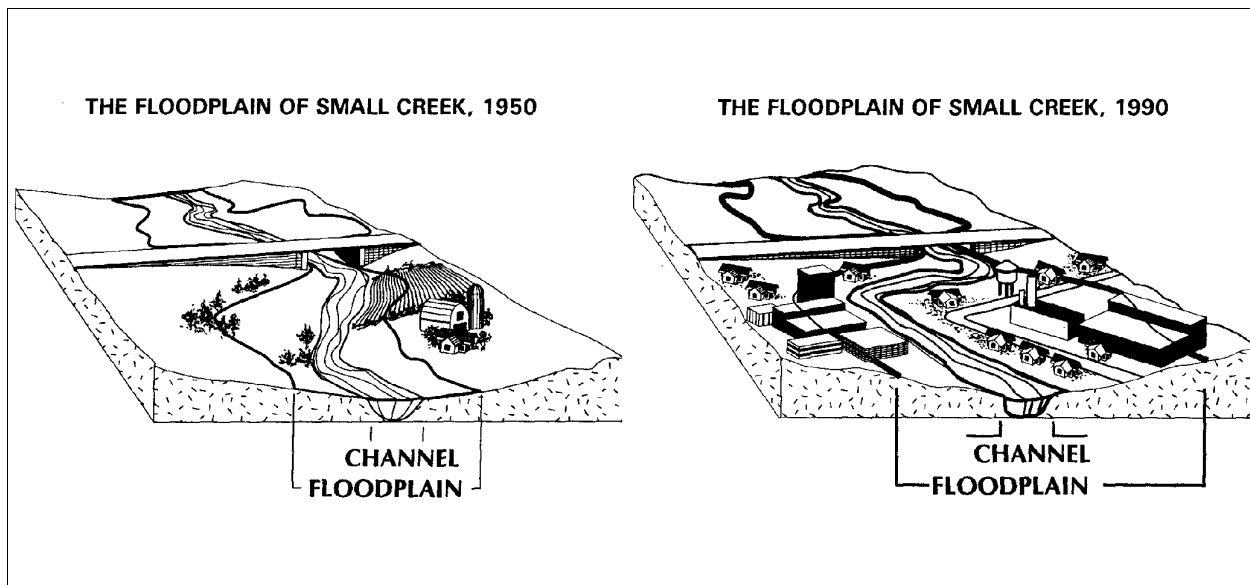


Figure 3-4. Schematic of Progressive Floodplain Development Source: ASFPM, 1997

Dams reduce the area and frequency of inundation on downstream floodplains by controlling the amount of water passing the dam location. The reduction in the area influenced by flooding causes a decrease in complex forms and beneficial functions in the ecosystem. Floodplain narrowing and conversion from wet to dry plant communities restricts the inundation of vegetated areas during normal seasonal high water periods. As a result of lowered nutrient and organic matter inputs from the reduction in flood extent, rearing habitats are diminished. Dams also tend to reduce the frequency and duration of bankfull discharge and restrict channel flow, leading to channel straightening and incision. Dams stop normal sediment transport in the downstream direction and erode the channel to bedrock below dams, eliminating spawning habitat.

Levees and dikes also tend to restrict the area of the floodplain exposed to flooding by constraining flows to the river channel, deepening the flow, and increasing flow velocities during flood stages. Typically, levees result in steep-sided trapezoidal channel cross-sections, rather than more natural compound channels with gentle bank slopes and flat-lying floodplain surfaces. The

corresponding high depth to width ratio of leveed channels is inherently unstable during high flows. Additionally, as levees modify the natural floodplain, flow velocities increase, gravel patterns change, side channels and wetland areas diminish, and water temperatures increase. These modifications lower the quantity of vegetative cover, decreasing shallow water habitats.

Channelization simplifies the form of the channel and floodplain environment by straightening the channel or separating it from side channel features. This reduces habitat values and water quality downstream, increases flow velocity and often leads to a lowering of the stream bed. Hardening the banks of a river, through the use of rip rap or concrete, can result in increased downward scour of the river bed during flood flows. A deepened river channel may subsequently convey normal flows at lower water surface elevations and lead to the lowering of adjacent floodplain water table conditions, dramatically changing the extent and composition of riparian vegetation (Figure 3-5).

Large wood removal is a specific channelization technique that can drastically change water flow, bank

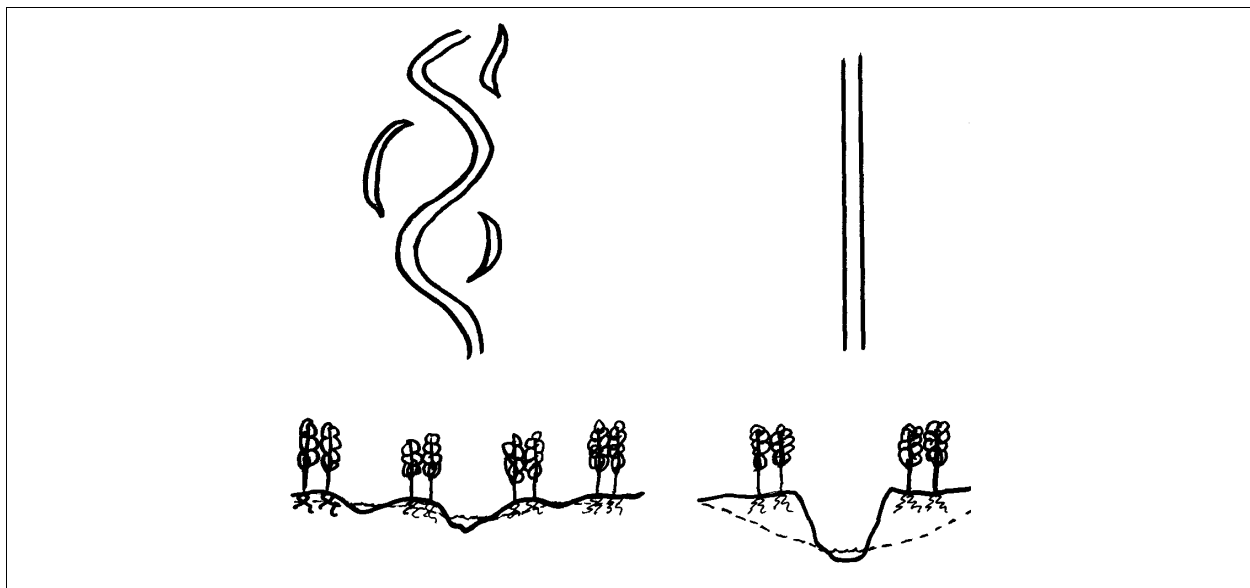


Figure 3-5. Floodplain Water Table Changes with Channelization Source: Malanson, 1993

erosion

trends,

and

sediment

deposition

patterns. Large

wood causes localized backwater flooding that leads to sediment accumulation and subsequent vegetative growth. Wood also absorbs flow energy, reduces stream velocities and creates secondary currents. These can create local scour pools that provide refuge and distribute gravel particles exposing sizes preferred by spawning salmon. Increased flow velocities caused by wood removal may accelerate channel instability and erosion damage to banks.

Gravel mining of the river channel and floodplain removes sediment delivered from the upland to lowland areas. When present, these sediments are reworked at high flows to create spawning gravels and land forms suitable for colonization by native plant species. The removal of gravels also causes an increase in stream power which can result in increased erosion.

Flooding was recognized by earlier cultures, and is still

recognized in some countries, as a natural resource that can be managed effectively to fertilize floodplains. By diking, channelizing and making economic developments that were not adapted to the natural flood cycle, this benefit was often turned into a cost.

In addition to the physical impacts from human alteration of floodplains, the long-term economic benefits of floodplain development are questionable. Flood damage trends continue to increase, despite the national investment in flood control (Figure 3-6). In addition to the costs to construct flood control works, the long-term operation and maintenance costs of these facilities is increasing (Figure 3-7). Maintenance becomes more significant over time because most structural flood control works were designed with engineering criteria and assumptions that ignored natural river system processes.

As a result of recurring natural impacts and an increasing understanding for the economic reality of floodplain investments, human perceptions of the value and function of the river system continue to evolve. We are realizing that engineering solutions are costly, only protect local regions, and require a tradeoff between flood damage reduction and ecological resources

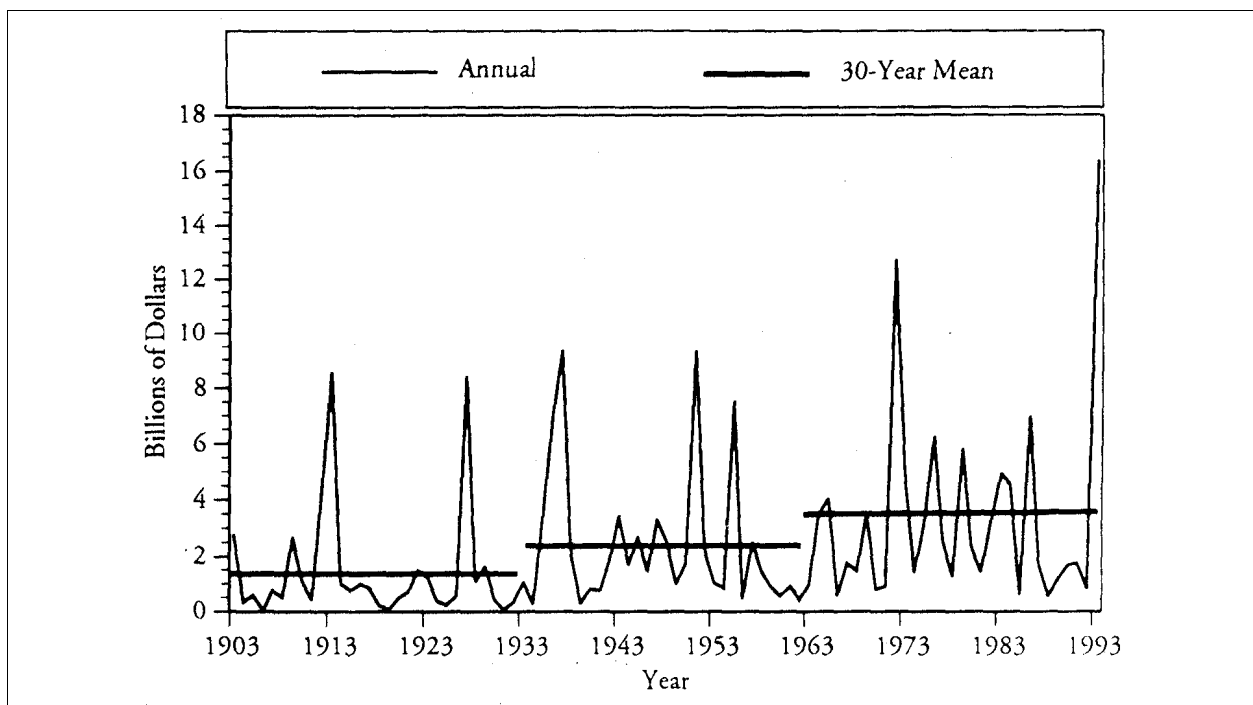


Figure 3-6. Flood Damage Trends for the United States. National average and 30-year mean flood damages, adjusted to 1993 dollars Source: Hey and Philippi, 1995

(Williams, 1994). Engineered solutions can also separate the community from the river, a valuable recreational and educational resource. Recent major floods and flood damages are prompting engineers to

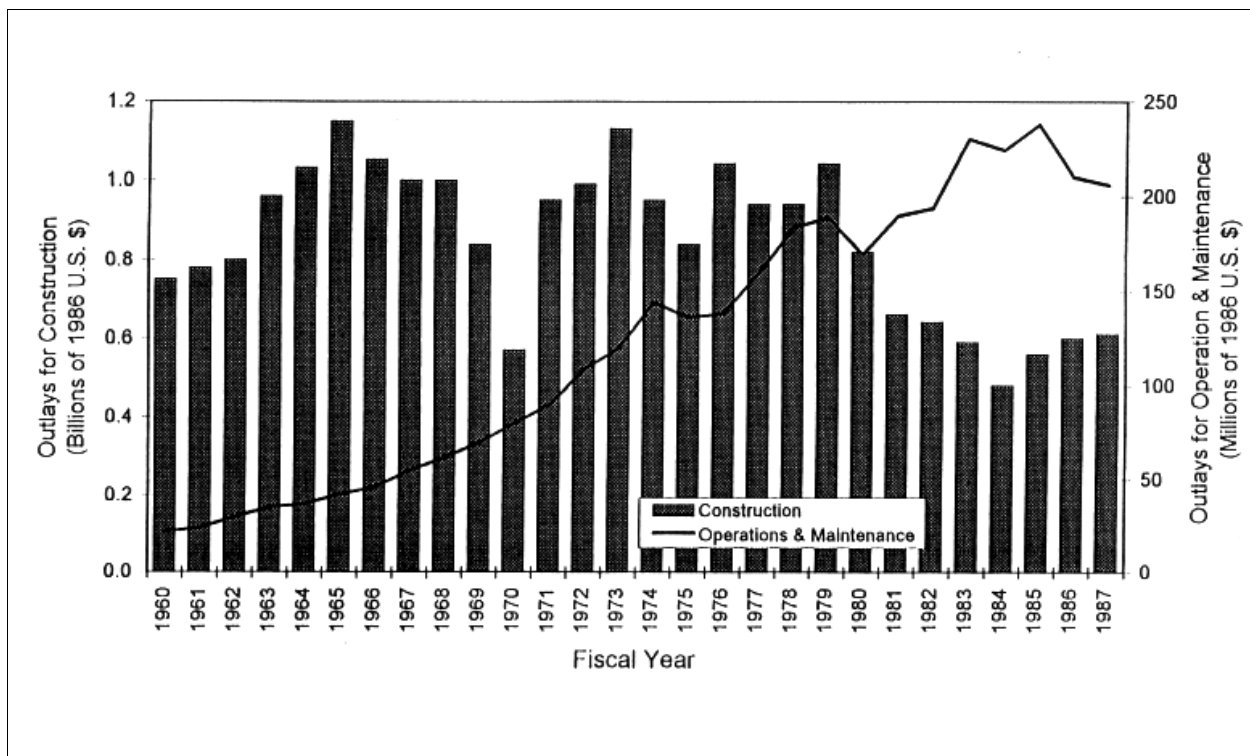


Figure 3-7. Flood Control Cost Trends in the United States Source: Rosen and Reuss, 1988

re-examine traditional methods of alleviating catastrophic flood hazards, and are causing us to rethink how we should handle floods in the future.

3.5 Trends in Floodplain Management

Our long-standing approaches to flood and fishery issues often work at cross-purposes to each other and end up achieving neither objective, i.e. increasing flood hazards and damages, as well as destroying salmon habitat. Many traditional approaches to river engineering are rooted in outdated economic or societal needs. Over the last century, societal goals for resource management have changed considerably from the time when Oregon's river engineering works were planned and implemented. Communities now value the environmental, recreational and aesthetic values rivers can provide, to a similar extent as the natural resources that have attracted us to rivers in the past. As a result,

there is a need to plan for the long-term sustainable use of rivers rather than for the short-term exploitation of these systems that characterized the era of river engineering.

Unlike flood *control*, (quoted earlier) which relies solely on the use of structural measures—dikes, levees, dredging—to eliminate flooding, flood *management* includes more non-structural techniques to reduce flood hazards, such as land use planning, floodplain restoration, flood warning/emergency response, and public education. The premise of flood management is the understanding that not all flooding can be eliminated and that the goal should be to reduce flood risk to lives and property in a cost-effective manner (Williams, 1994).

Flood management also results from popular public opinion that wishes rivers to be more than just flood conveyance canals. Often, many objectives are

specified at the start of a project. Effective “multi-objective” flood management is broader than a single focus on flood control, and requires the right mix of flow management, ecosystem management, and people management efforts (Figure 3-8) to effectively resolve flood problems and reduce the need for emergency flood response and recovery. Structural flood control measures remain important as elements in a river management strategy, but they are no longer the predominant element for meeting today’s societal demand for a multi-objective focus.

Flood management also requires substituting “management” for “construction” as the most important activity for protecting floodplain investments. This in turn emphasizes the need for more sophisticated and effective maintenance, operations, flood warning, training, monitoring, and learning from experience to enable a cycle of constant improvements in river system management.

Trends in floodplain management are beginning to reflect the changing concerns of decision-makers. These include combinations of water resources, water quality, and flood defense objectives. Increasingly, these traditional objectives are leavened with consideration for fish and wildlife habitat and the importance of riparian areas for maintaining biodiversity. The historical focus on single-function management of river systems is gradually giving way to the multi-functional perspective, partly as a result of greater demands being placed on natural resources in general and water resources in particular.

Referring to the several routes of change towards a more sustainable water environment in Figure 3-9, there has been significant institutional and legislative change in the last two decades in the United States. For example, guidelines for FEMA mapping of floodplain lands has recently been expanded to allow consideration for migrating river channels and future

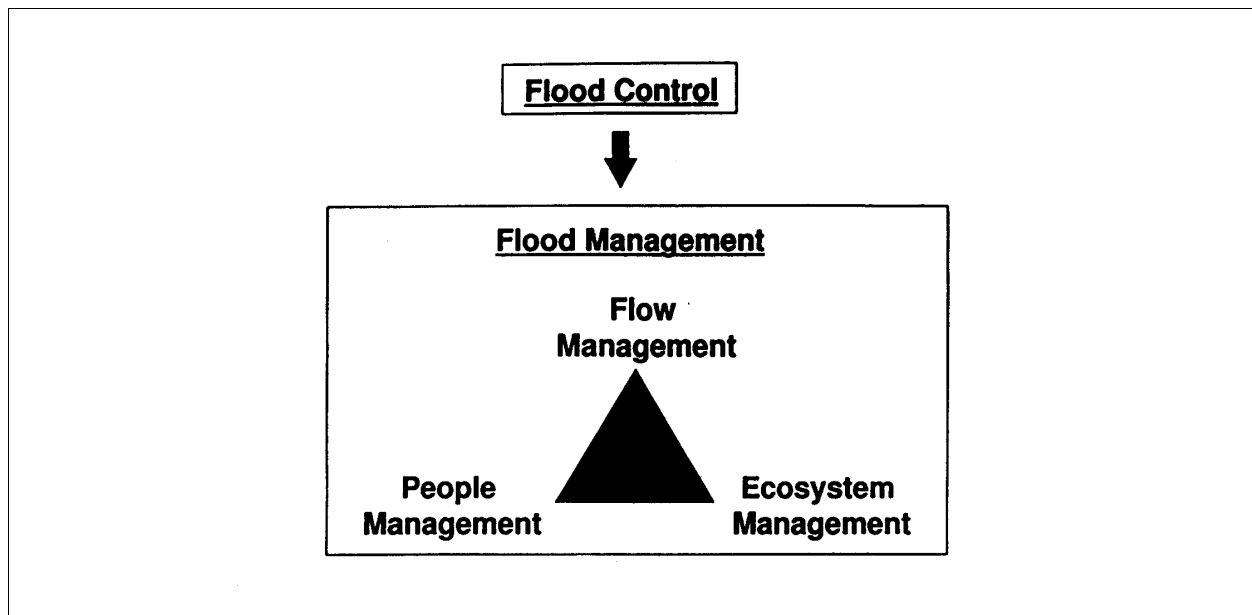


Figure 3-8. Policy Evolution from Flood Control to Flood Management. The evolution from “flood control” policy to “flood management” policy. Flood management policy requires an equivalent focus on managing ecosystems, flows, and people and their actions. Source: Haeuber and Michener, 1998

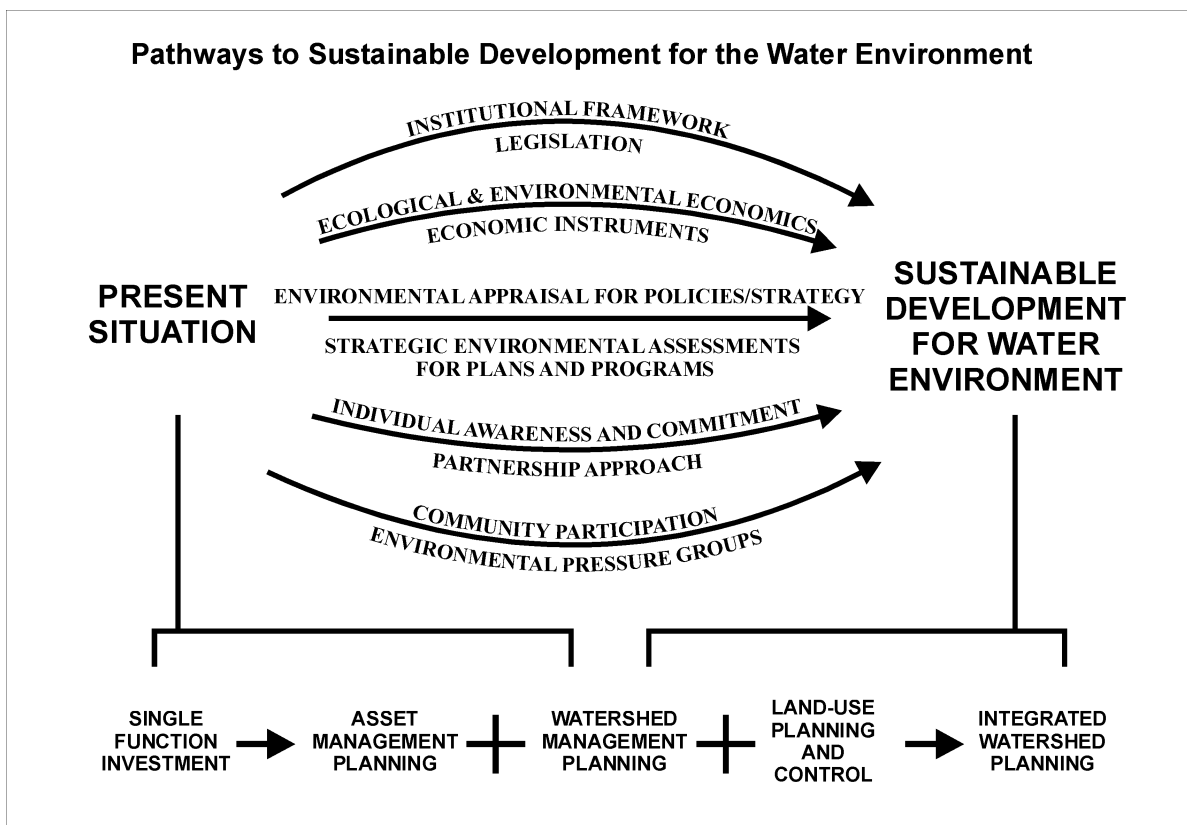


Figure 3-9. Pathways to Sustainable Development for the Water Environment

conditions hydrology. Also, US Army Corps of Engineers has a new mandate for ecological enhancement. The Endangered Species Act (ESA), with its requirement to preserve the habitat of threatened and endangered species, has far-reaching implications for integrated floodplain management. Virtually all aspects of the environment are impacted by the broad mandate of ESA. Thus, natural resource agencies such as the Division of State Lands in Oregon and federal agencies such as NMFS, USFW and FEMA, have emphasized the contributions of floodplains to healthy fish habitat. This habitat includes floodplain connectivity with streams, rivers, and sloughs as well as riparian habitat.

In the last few years, many federal agencies are coordinating their environmental review requirements to stimulate compliance with the ESA. For example, FEMA's current requirements for flood repair have been modified since the floods of 1996 to consider the integration of habitat restoration and ecosystem functionality.

Projects that use federal funds trigger a "federal nexus" which requires an Environmental Impact Assessment, including identification of cumulative impacts. Any development will require analysis of the hydrological regime, including impacts on flow regime, water balance, water quality and presence or absence of riparian vegetation. The EPA has developed guidelines which summarize the steps of the Cumulative Effects Analysis. They include:

1. Identify the significant cumulative effects associated with the proposed action and define the assessment goals.
2. Establish the geographic scope for the analysis.
3. Establish the time frame for the analysis.
4. Identify other actions affecting the resources, ecosystems, and human communities of concern.

Many communities are requiring a Cumulative Effects Analysis even when no federal funds are involved, because this methodology establishes benchmarks which can be used for mitigation.

In the last decade, there has been a marked increase in activity by individuals and non-governmental organizations to conserve and enhance rivers and floodplains. Many river groups have gained wide support from communities and regulatory agencies through awareness campaigns and political action. This development is especially strong in the U.S. where substantial funds have been raised from private donations, foundations, and government grant programs.

Efforts to improve the water quality of river systems are increasingly taking a close look at the degradation of floodplain lands. In recent decades, point-source pollution (pollution from pipe discharges and other discrete locations) was the focus of regulatory efforts, and this type of pollution has been substantially reduced. Attention has now turned to diffuse, or non-point, sources from agricultural and urban runoff. Floodplains are especially vulnerable to this form of pollution. Source control techniques are being applied as management strategies, to reduce the amount of non-point pollution generated, and the value of using vegetation to treat polluted runoff is now widely recognized and included in best management practices for surface water management.

At the same time, recent initiatives in assessing and improving the efficiency of industrial processes have shown that remarkable progress can be made in reducing water usage and improving the quality of waste streams, with payback periods of less than one year. The wider application of such investigations will do much to reduce the "ecological footprint" of industries situated in floodplains.

Economic incentives programs are now being used to

assist the restoration of floodplains to more appropriate uses. This is fitting, since much of the deterioration of floodplains has been promoted by economic incentives for development that failed to take into account the intrinsic values of the floodplain itself. Pilot programs, such as one around the northern edge of Klamath Lake, have shown improved farming efficiency with the adoption of short-term rotational grazing, which allows economic wetland regeneration in floodplains. The principle underlying these improvements is that the natural resource is not exhausted before moving on – grass grazed to within two or three inches of the ground recovers much more quickly than grass grazed to its roots.

The success of community-based initiatives such as the Urban Streams Restoration Program in California, illustrates the need for community involvement in decision-making over floodplain management. With better understanding of the inter-connectivity of the river system, communities are coming together to agree

on more sensible uses of the resource, acknowledging that the actions of upstream landowners can have profound effects on the livelihood of their downstream neighbors.

It is worthwhile to note that despite policy-level and grass roots movement toward environmentally sensitive floodplain management and flood response, significant opportunities associated with the 1996 flood event in Oregon were lost simply because appropriate integrated river management strategies were not yet in place. For example, under post-flood emergency conditions, and without an alternative plan for flood response, flood control facilities and buildings were in many cases rebuilt to pre-flood conditions, where many might have been reconsidered in light of newer priorities. This illustrates that implementation of sound floodplain management is best done sooner rather than later, i.e. before, rather than after, the next major flood event.